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# A collaborative multi-faculty approach to increase engineering competency through on-line discussions

**Lisa B. Bosman†, Walter McDonald‡ & Kurt Paterson***

Purdue University, West Lafayette, IN, United States of America†
Marquette University, Milwaukee, WI, United States of America‡
James Madison University, Harrisonburg, VA, United States of America*

ABSTRACT: Entrepreneurship is an economic driver and important aspect of the global economies; yet few engineers have the requisite training for entrepreneurial success. In this article, the authors outline the design, development and assessment of a semester-long faculty professional development programme for engineering educators at two universities; this training aimed to teach engineering instructors how to incorporate entrepreneurially-minded on-line discussions into traditional engineering classrooms. On-line discussions were chosen as *low hanging fruit* in that they require limited class time, allow instructors to provide immediate student feedback, afford students the necessary time for creating thought provoking responses and promote connecting rigorous classroom topics to real-world experiences. A mixed-methods research approach was used. The findings suggest a positive faculty response to the training and implementation of entrepreneurially-minded on-line discussions in the engineering classroom. Furthermore, the results suggest that the majority of faculty participants will continue use of on-line discussions in future sessions and different classes.

## INTRODUCTION

The *Entrepreneurship for All* crusade has many university campuses and communities offering campus-wide initiatives in the form of new centres, new degrees, new minors, new courses, new accelerator programmes and new student organisations. Many engineering faculty (academic staff) are jumping on the entrepreneurial bandwagon due to the natural connection between engineering design and opportunity recognition associated with entrepreneurship. Here, the demand for entrepreneurially minded curriculum is not limited to a specific engineering discipline or career path, instead, it is important for all types of engineering students to leverage expertise and stimulate value creation regardless of the application or job [1].

Observation and anecdotal evidence suggests two potential camps of faculty. One group of engineering faculty is thinking about commercialisation of research work (through IP development, start-ups and partnerships), and the second group is thinking about contemporary engineering competencies needed for graduates to flourish in an array of workplaces. As such, the rate of adoption continues to increase for new engineering faculty incorporating entrepreneurship frameworks and concepts into the classroom [2].

Increased integration of entrepreneurial frameworks in the classroom has been supported in recent years by new conferences, journals and movements. The American Society for Engineering Education (ASEE) Annual Conference has the Entrepreneurship and Engineering Innovation Division (ENT). This forum provides a platform for researchers to get peer feedback and disseminate assessment approaches to the broader engineering education community. The Journal of Engineering Entrepreneurship (JEEN), established in 2009, is a peer-reviewed international journal focused on advancing the integration of entrepreneurship principles in the engineering classroom. Additionally, due to the interdisciplinary popularity between engineering and entrepreneurship, other journals have been known to regularly offer special issues, including the Journal of Engineering Education, Advances in Engineering Education, and Entrepreneurship Education and Pedagogy.

However, despite new conferences and journals on entrepreneurship, the education research community has struggled to keep up with the rapid adoption by engineering educators. As a result, validated entrepreneurial engineering education research assessments are limited. Those assessment instruments that do exist lean towards business creation or management, with limited regard for engineering-specific entrepreneurship assessment and outcomes [3].

In addition, many of these initiatives are strong in content creation, but weak in faculty development efforts, leaving most university faculty to share good practices informally and without sound pedagogical support. This article directly addresses this gap by showcasing the design, deployment and results of a professional development opportunity aimed to increase engineering faculty understanding towards implementing entrepreneurially-minded on-line discussions into traditional engineering courses. The article provides examples of engineering-specific entrepreneurship assessments and outcomes, grounded in the Kern Entrepreneurial Engineering Network (KEEN) framework, implemented in engineering courses at two different universities.

## BACKGROUND

### Relationship between Engineering and Entrepreneurship

Development of an entrepreneurial mind-set is critical for future engineers, because engineers have a foundational role in economic growth, from a macro and micro perspective [1]. From the micro perspective, the iterative engineering design process can take many forms [4][5],but common steps are as follows: 1) define the problem; 2) brainstorm ideas; 3) plan solutions; 4) make a model; 5) test the model; and 6) reflect and redesign. Throughout this iterative design process, the ultimate goal is to create the most valuable design taking into consideration customer desirability, technologically feasibility and business viability [6]. The iterative and continuous nature of the quest to validate the most valuable design can be considered from a more macro perspective as the design improves over time from an initial discovery to evaluation, and finally exploitation [7].

The role of engineers in this entrepreneurial process has been formulated within several innovation and entrepreneurship frameworks, which aim to identify the characteristics, behaviours or outcomes associated with the entrepreneurial mind-set. The entrepreneurial orientation framework suggests pro-activeness, (calculated) risk-taking, and innovativeness as core characteristics of the entrepreneurial mind-set [8][9]. The innovator’s DNA states that innovative entrepreneurs display behaviours including associating, questioning, observing, experimenting and networking [10].

Neck and colleagues’ book, *Teaching Entrepreneurship: a Practice Based Approach*, posits that entrepreneurial thinking is driven from practicing empathy, play, reflection, experimentation and creation [11]. The Entrepreneurial Strengthsfinder, found that successful entrepreneurs had personality traits related to confidence, independent, creative thinker, promoter, knowledge-seeker, determination, risk-taker, relationship-builder, business focus and delegator [12]. The KEEN framework, although anecdotal in its grounding, proposes that the entrepreneurial mind-set is nurtured through curiosity, connections and creating value (commonly referred to as the 3 C’s) [13]. Due to the KEEN framework’s specific focus on engineering undergraduate education, the faculty professional development experience was grounded in the 3 C’s.

### Overview of the KEEN Student Outcomes

The Kern Entrepreneurial Engineering Network (KEEN), supported by the Kern Family Foundation, is a network of 42 institutions and hundreds of engineering faculty. KEEN’s mission is as follows:

> *We are a national partnership of universities with the shared mission to graduate engineers with an entrepreneurial mindset so they can create personal, economic, and societal value through a lifetime of meaningful work.*

This mission is advanced through the KEEN framework, which can be used as a guide to develop engineering-specific entrepreneurially-minded learning (EML) assessment and outcomes. The KEEN framework was developed to combine the entrepreneurial mind-set with engineering education to produce a more valuable, strategically-prepared engineer, rather than simply an *obedient engineer*. The KEEN student outcomes include: 1) curiosity (demonstrating constant curiosity about our changing world and exploring a contrarian view of accepted solutions); 2) connections (integrating information from many sources to gain insight, as well as assessing and managing risk); and 3) creating value (identifying unexpected opportunities to create extraordinary value and persisting through and learning from failure).

Many studies have investigated the role of the KEEN 3 C’s in the higher education engineering classroom, spreading the gamut of introductory design courses, mid-level foundational engineering courses, and even the humanities. Huerta and colleagues applied thematic analysis to student written reflections submitted upon completion of a first-year engineering design project; the study results suggest that students thought process revealed actions related to facets of the entrepreneurial mind-set [14].

Tabrizi implemented and assessed the incorporation of KEEN-based producer-customer innovative laboratory assignments into a course titled *Computer Architecture and Organization*, where anonymous student feedback has been encouraging and resulted in the continuous deployment of laboratory assignments [15].

Liu and colleagues developed a three-course problem-based learning experience grounded in the 3 C’s, which assessment results suggest evidence of fostering the entrepreneurial mind-set across junior and senior mechanical engineering students taking Fluid Mechanics, Heat Transfer and Mechatronics [16]. Riley implemented a case study approach to integrating the KEEN entrepreneurial mind-set into engineering curriculum [17]; the use of real-world applications answers a question commonly heard by engineering students - *when will I ever use this?*

On-line Discussions

On-line discussions provide many benefits for both face-to-face classrooms and on-line courses [18-20]. First, they afford a wide range of personalities the necessary time to read, reflect and respond in more than cursory fashion. Second, they provide students the opportunity to read and gain insight from other students' posts. Finally, they give instructors the chance to provide rapid student feedback and ask further questions to dig deeper into the subject at hand. Incorporating the KEEN 3 C's into on-line discussions has been explored at an individual faculty level [2]; however, until now, limited opportunities have been offered to scale the approach to include multiple faculty and multiple universities. In this study, the KEEN framework is used as a foundation for on-line discussions to determine if the framework influences the ability of engineering educators to go beyond the topic and connect the theoretical classroom to real world, practical experiences.

METHODS

Participants

During fall 2017, a total of seven engineering faculty enrolled in the semester-long professional development programme on posing essential questions (EQs), including three from University A and four from University B. EQs can be thought of discussion prompts integral to general engineering topics or specific disciplines. Participation in the programme required attending an initial 3-day training workshop in August 2017, implementation of the new curriculum in the fall 2017 semester, and submission of reporting and assessments. Upon completion of the initial semester-long professional development programme, the faculty participants implemented EQs in the following engineering courses during the fall 2017 semester:

- Engineering Opportunities (required first-year engineering course);
- Engineering Design 1 (required sophomore engineering course);
- Engineering Design 3 (required junior engineering course);
- Hacking for Diplomacy (elective senior engineering course);
- Water Resources Planning and Management (environmental engineering course);
- Embedded Systems Design (electrical engineering course);
- Fundamentals of Heat Transfer (mechanical engineering course).

Participation Requirements

The initial 3-day training workshop was held at the University A campus, located in Midwest USA in August, 2017. As such, for the participants that travelled from University B (located on the East Coast USA), all travel expenses were covered. Participants received clear expectations up front that would result in a financial stipend upon completion of the following requirements: 1) August 2017: participate in a 3-day training on the University A campus; 2) fall 2017 semester: develop and deploy 8 EML discussion prompts in the engineering classroom; 3) September and October 2017: monthly check-in; and 4) December 2017: final reporting.

Data Collection

Table 1: Participant related data collection information.

| Instrument | Time period |
|---|---|
| August workshop presentation (qualitative) | End of August 2017 |
| September check-in report (qualitative) | September 2017 |
| October check-in report (qualitative) | October 2017 |
| Final report (qualitative) | December 2017 |
| Final survey (quantitative) | December 2017 |

Data was collected throughout the programme, as shown in Table 1. All data collected has institutional review board (IRB) approval by both University A and University B internal review boards. Data collection instruments use a combination of qualitative and quantitative approaches.

Example Engineering-specific Entrepreneurial Assessments and Outcomes

A core feature of the workshops was conveying the important elements of good essential questions. Each EQ discussion prompt includes four components: 1) learning objective; 2) hook; 3) initial prompt; and 4) response prompt. An example is provided here for an environmental engineering course on Water Resources Planning and Management.

Learning objective: Identify and discuss the economic implications of environmental regulations through a case study example of the Clean Water Act.

Hook: Water extinguishes fires, it does not cause them. However, that was not the case in 1952 as the Cuyahoga River in Cleveland, Ohio, caught fire. The river catching fire was not due to natural forces, but the unregulated dumping of industrial and municipal wastes in the river. This environmental crisis along with many others resulted in the Clean Water Act, which regulates the discharge of industrial and municipal wastes into water bodies of the nation. This is a seminal piece of environmental legislation as it has dramatically improved the nation's waterways, so that now one can enjoy the beneficial uses - fishing, swimming, drinking - of the surface water bodies. However, passage of this legislation came at a cost. Businesses were now required to implement expensive treatment and waste management programmes to prevent unregulated discharges into surface water bodies.

Initial prompt: Find an example, such as the Cuyahoga River catching fire, that was addressed through the Clean Water Act or its subsequent amendments. Look through multiple sources to determine what the environmental concern was, how it was addressed through the clean water act, and what the remediation actions were. Finally, identify the actors that bore the financial burden of complying with the Clean Water Act.

Response prompt: Respond to at least two of your classmates post by answering one of the following questions. Even though complying with regulations has a financial cost, what might the economic benefits of regulatory compliance be in this example? Who benefits from clean water in this example? Do you think the benefits outweigh the costs?

Example student post for initial prompt: *On October 1, 1994 a backhoe operator, working under the supervision of Edward Hanousek Jr, struck a high-pressure petroleum pipeline. Unfortunately, this pipeline was running parallel to the Skagway River located near Skagway, Alaska. Hanousek's construction crew was not using any safety measures to protect the pipeline from damage during construction. The pipeline leaked about 5,000 gallons of oil into the river and Hanousek was charged and convicted of negligently discharging a harmful quantity of oil into a navigable water of the United States, which is in violation of the Clean Water Act. Hanousek had to serve six months in jail, six months in a halfway house, six months of parole, and pay a $5,000 fine.*"

Example student post to response prompt: *In this case especially, the humans and wildlife and watershed would benefit from this clean water. According to the 2010 census, the population of Skagway, Alaska was 920 people, but the tourist season brings and estimated 900,000 people through the town proper. So those people would be effected majorly by a large spill like that. There isn't a ton of fishing or economic dependency on the river, but those tourists who come to visit use it for leisure and things of that nature. I think that to set an example and precedent, the benefits outweigh the costs. Especially since it wasn't a massive spill and didn't kill a bunch of wildlife or people. It cost the man who was in charge a few months of his life, and a relatively tiny amount of money, but to enact more specific regulation that could prevent larger problems and issues in the future*.

## ANALYSIS, RESULTS AND DISCUSSION

### Qualitative Analysis

The NVivo 12 qualitative analysis software was used to analyse the qualitative data including the 1) August workshop presentation; 2) September check-in report; 3) October check-in report; 4) final report; and 5) facilitator observations. All data documents were imported into NVivo and each of the documents was read through several times. The documents were coded and themes were identified as shown here.

Faculty perceive the experience as positive: Most all the faculty participants found parts of the new pedagogical approach beneficial as both a teaching tool and learning opportunity:

- *Prompts can be used to introduce material that is then covered in class.*
- *The prompts are serving as an excellent driver of critical project considerations. The students are taking them seriously even though the course has significant deliverables.*
- *Questions can be asked before a lecture topic to ensure preparation.*
- *The discussion prompts are well integrated into the course, and they seem to be an integral part of the overall learning experience.*
- *Students are responding, and there are signs that at least some of them are doing quite a bit of extra research outside the textbook.*
- *Students are engaged in the discussions and bring the discussion to class.*

Challenges do exist: The faculty participants were open to explaining challenges, many of which were followed up with potential solutions:

- *Timing. I had the responses due on Saturdays (after initial prompts due on Thursdays), the students asked for them to be due on Sundays, so we made that change.*
- *Students have struggled to figure out how to* find *the rubric that is being used to score discussion prompts. Students have also struggled to figure out how to imbed images into their discussion prompts. I have had to make posts to (the learning management system) providing instructions for how to do this.*

- *Scheduling the prompts within the course has been a struggle.*
- *Placing forum topics to match well with the lecture topics has been a bit tricky. I have been assigning approximately 10 days for initial post and one week for reply.*
- *While most posts are good-quality content-wise, not all posts follow exact organizing/formatting directions mentioned in the prompt. I do not moderate or post in the forums to keep the discussion sort of free-flowing. Hence I have been ignoring this inconsistencies as long as the content and quality of posts are good.*
- *Students seem to be less argumentative than I expected them to be, particularly when it comes to criticize a peer's choice! I am not sure it is a challenge, but it is an observation.*
- *We've transitioned into projects and design challenges and it seems that it is too much to have students working in groups on the design challenges AND filling out discussion prompts.*
- *Slow response initially. Need to send email reminders the day before initial prompt or response prompt were due.*

Sharing of best practices: The faculty participants were very open to sharing what worked and what did not work, in addition to tips and tricks for successfully deploying discussions.

- *Require students to respond to an initial post that has not had a response yet so that no student posts are neglected from the response discussions.*
- *I put all nine EQs into Canvas (our LMS) at once, set their publication dates, and let the system post them automatically as their semester unfolds.*
- *Send email reminders the day before it is due.*
- *Canvas best supports discussion questions that an individual can answer.*
- *I feel it would be good to take a pulse of the class as how much time they are spending for the forum beyond regular classwork and homework. I have done it informally, but will do an anonymous survey (mid-semester). I am using self-assessment for grading the discussion forum.*

Quantitative Analysis

Table 2: Likelihood of using on-line discussions again.

| Question | Average (n = 7) |
|---|---|
| What is the likelihood that you will continue using on-line discussions in this course? | 4.0 |
| What is the likelihood that you will add on-line discussions to other courses? | 3.9 |

Table 3: Integration of KEEN outcomes into discussion prompts.

| KEEN student outcome | Average (n = 7) |
|---|---|
| Demonstrate constant curiosity about our changing world | 4.0 |
| Explore a contrarian view of accepted solutions | 3.3 |
| Integrate information from many sources to gain insight | 3.9 |
| Assess and manage risk | 2.3 |
| Identify unexpected opportunities to create extraordinary value | 3.4 |
| Persist through and learn from failure | 3.3 |

A final survey was completed by faculty participants upon completion of the semester. One of the questions asked faculty participants to consider the likelihood of using on-line discussions again in the present course and in other courses. Specifically, participants were asked to respond to the likelihood of using on-line discussions again in the current class and in other classes, using a scale of (very likely = 5, neutral = 3, very unlikely = 1). The results are shown in Table 2, which provide positive self-reported intentions for future use of on-line discussions in the engineering classroom.

Another final survey question asked faculty participants to what extent the KEEN educational outcomes were incorporated into their essential questions. Specifically, participants were asked: *To what extent did your online discussions emphasize the following in this course?* (very much = 5, some = 3, very little = 1). The results are shown in Table 3. The two most commonly applied KEEN outcomes are: *Demonstrate constant curiosity about our changing world* and *Integrate information from many sources to gain insight.*

CONCLUSIONS

The results suggest that the faculty participants were satisfied with the semester-long professional development experience. Furthermore, findings imply the faculty participants will continue use of on-line discussions in future sessions and different classes. Lastly, based on observation and anecdotal evidence, the professional development opportunity fostered faculty collaboration and networking both within and across universities. It may be that structured faculty development initiatives can serve as critical catalysts for change, but also for collegial community-building.

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